Appendix IV-04 A

PRESTRESSED GIRDER DESIGN

There are two prestressed girder design programs:

HW8030 - To be used for ND standard box girders and the AASHTO standard I girders.

HW8035 - To be used for the modified I girders supplied by ND Concrete Products.

The input for both is as shown on the input sheet for HW8030. Both programs design for 424 psi tension in the bottom of the beam under final forces. The program also checks the ultimate strength to make sure that it is greater than the factored loads. Under some conditions, ultimate strength is the controlling factor; thus, the final tension will be less than 424 psi. When this condition occurs, the PC program could run for five (5) minutes.

Something to check is that the right program is run for the beams used. In the title block on the first page of output, the programs are labeled.

For HW8030 it says - AASHTO I girders or ND Standard Box Girders.
For HW8035 it says - Modified I Girders.

Another check is in the upper right corner of the second and third pages (HW8-030-AA or HW8-035-AA).

Something else to note is that the detension stress will vary if the ultimate strength controls. The highest detension for the range of C.G.s should be shown on the plans.

After a girder has been designed, a check should be made to see if it can be built. For example: the number of strands required to get the final force may not fit into a beam. The C.G. shown may not be realistic compared to the number of strands required. The best way to accomplish this is to try to an actual strand pattern.

The check program should be run to insure that the detension is correct. If the stress losses are greater than the assumed 45,000 psi, the detension stress will increase. To determine the number of strands required, divide the final force by 24.0975 K/ strand (if ½" Ø 270 ksi low relaxation strands are used).

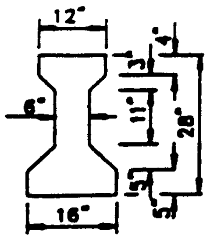
The live load deflections should also be checked to insure that it is acceptable.

CHECKING OF PRESTRESSED SHOP DRAWINGS

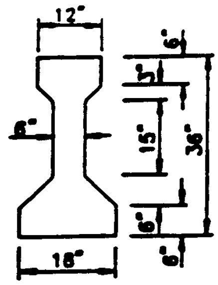
Use either HW8030 or HW8035, whichever is appropriate. Check the output to make sure the correct program was used.

Check the detension (f'ci x .6) and final acceptance (f'c x .4). The maximum allowable initial tensile stress is 3 f'ci up to 200 psi. For 4,000 psi, f'ci the allowable is 190 psi T. The maximum allowable final tensile stress in bottom of the beam is 6 f'c. The maximum stress for f'c = 5,000 psi is 424 psi T.

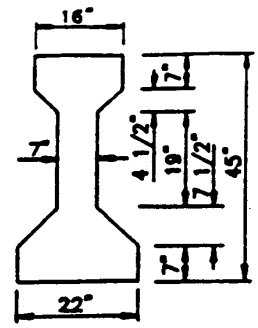
Another thing that must be checked is the ultimate strength. Both programs generate the ultimate strength and factored loads. If the factored loads are greater than the ultimate strength, the beam is not adequate. The program will print a warning if the factored loads are greater than the ultimate strength.



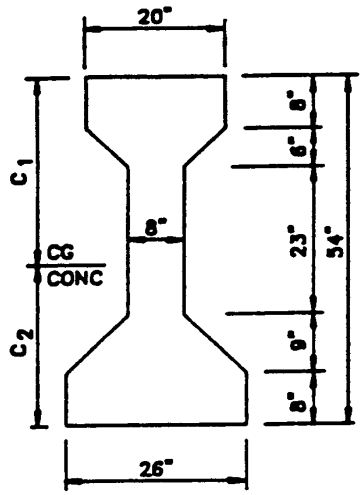
TYPE I
35 TO 45 FT.



TYPE II
40 TO 50 FT.



TYPE III
55 TO 80 FT.



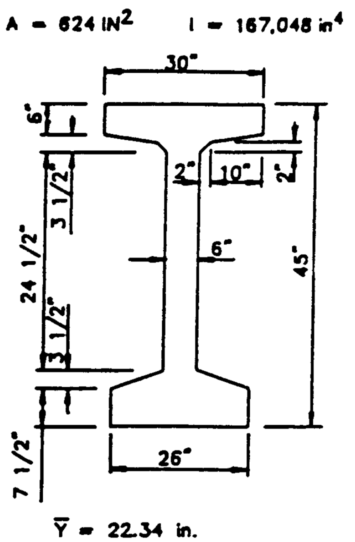
TYPE IV
70 TO 100 FT.

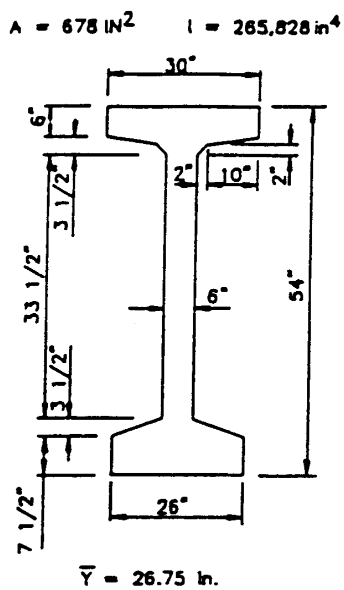
TABLE A.11 SECTION PROPERTIES OF AASHTO BRIDGE GIRDERS

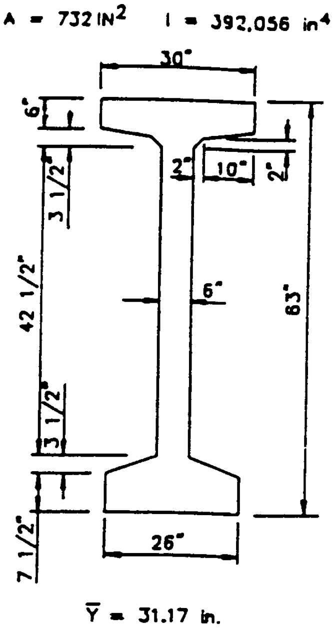
Type	h in.	A_c in.^{2}	I_c in.^{4}	c_1 in.	c_2 in.	r^2 in.^{2}	w_0 plf
I	28	276	22,750	15.41	12.59	82	288
II	36	369	50,979	20.17	15.83	138	384
III	45	560	125,390	24.73	20.27	224	583
IV	54	789	260,741	29.27	24.73	330	822

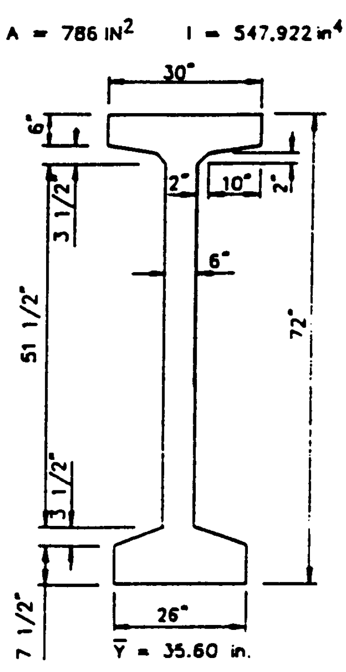
Type		Nominal Diameter in.	Nominal area in.^{2}	Nominal weight lb/ft
Seven-wire strand (Grade 250)	1/4	(0.250)	0.036	0.12
	5/16	(0.313)	0.058	0.20
	3/8	(0.375)	0.080	0.27
	7/16	(0.438)	0.108	0.37
	1/2	(0.500)	0.144	0.49
		(0.600)	0.216	0.74

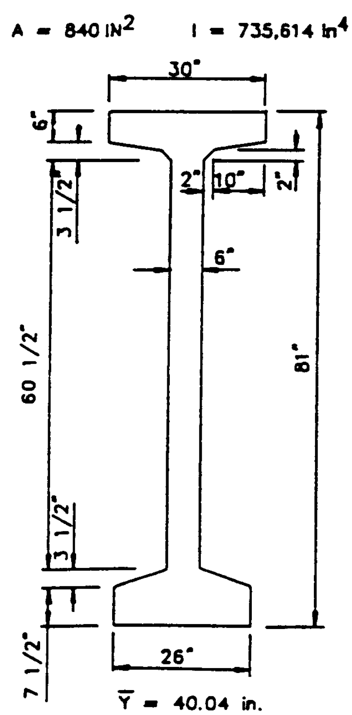
Type		Nominal Diameter in.	Nominal area in.^{2}	Nominal weight lb/ft
Seven-wire strand (grade 270)	3/8	(0.375)	0.085	0.29
	7/16	(0.438)	0.115	0.40
	1/2	(0.500)	0.153	0.53
		(0.600)	0.215	0.74


A = 624 IN2 I = 167,048 in4
30"
6"
3 1/2"
2"
10"
2"
24 1/2"
6"
45"
3 1/2"
3 1/2"
7 1/2"
26"
Ȳ = 22.34 in.


A = 678 IN2 I = 265,828 in4
30"
6"
3 1/2"
2"
10"
2"
33 1/2"
6"
54"
3 1/2"
3 1/2"
7 1/2"
26"
Ȳ = 26.75 in.


A = 732 IN2 I = 392,056 in4
30"
6"
3 1/2"
2"
10"
2"
42 1/2"
6"
63"
3 1/2"
3 1/2"
7 1/2"
26"
Ȳ = 31.17 in.


A = 786 IN2 I = 547,922 in4
30"
6"
3 1/2"
2"
10"
2"
51 1/2"
6"
72"
3 1/2"
3 1/2"
7 1/2"
26"
Ȳ = 35.60 in.


A = 840 IN2 I = 735,614 in4
30"
6"
3 1/2"
2"
10"
2"
60 1/2"
6"
81"
3 1/2"
3 1/2"
7 1/2"
26"
Ȳ = 40.04 in.

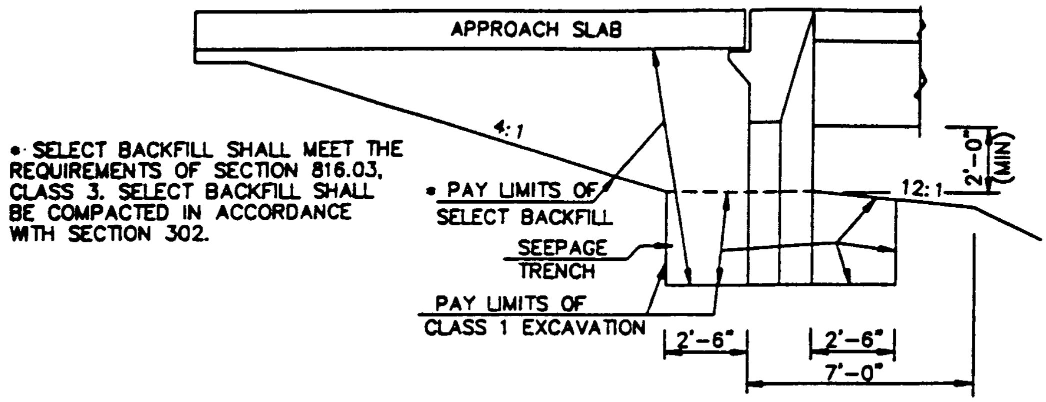
Appendix IV–04 B Flared Back Parapet Wall and Safety Shape Transition

Standard Drawing D–764–3	W BEAM GUARDRAIL AT BRIDGE END– General layout and details–Flared guardrail section.
Standard Drawing D–764–3 A	THRIE BEAM TO W BEAM–TRANSITION AND CONNECTION TO DOUBLE BOX BEAM RETROFIT

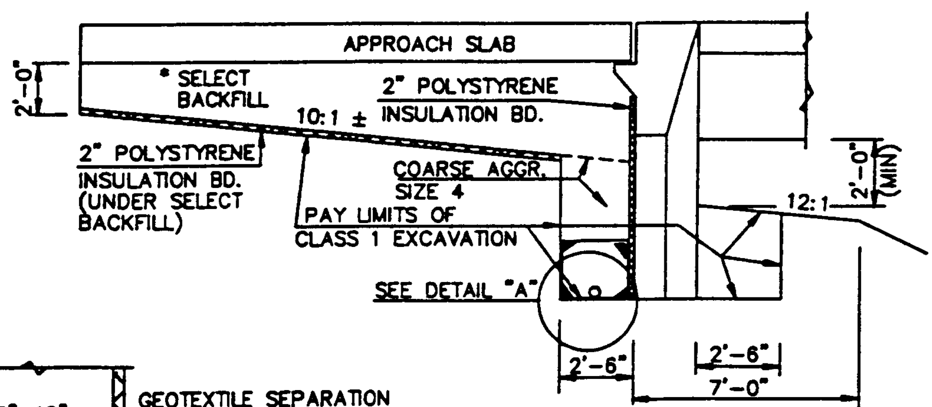
Appendix IV-04 C Approach Slab Details

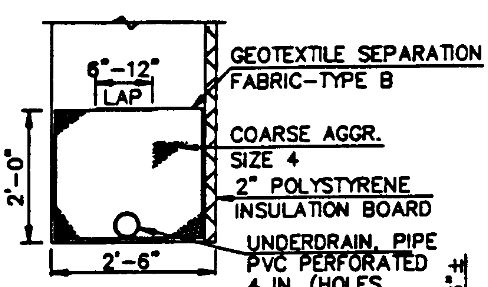
APPROACH SLAB DETAILS

THE FOLLOWING DRAWING SHOWS THE GENERAL FEATURES OF EXCAVATION AND BACKFILL FOR SITES OTHER THAN THE RED RIVER VALLEY.

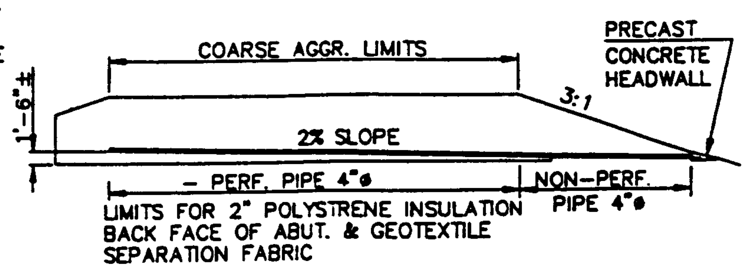


THE FOLLOWING DRAWING SHOWS THE GENERAL FEATURES OF EXCAVATION, BACKFILL, INSULATION AND DRAINAGE FOR SITES IN THE RED RIVER VALLEY.





DETAIL "A"



BACK FACE OF ABUTMENT

Appendix IV-04 D

PREDETERMINATION OF PILE LENGTHS BASED ON ANALYSIS OF SOIL PROPERTIES

1. APPLICATION

By inspection of the soil borings, break the subsoil into specific zones or stratums. This can be done individually or as a group, depending upon the horizontal cross-sectional similarity of the material. Utilize the standard penetration test results, soil description, and the laboratory determination of the physical properties of the soil in establishing zones.

Lengths are determined by computing supporting capacity of the zones penetrated. Estimated penetration will be at the elevation which the computed capacity equals the required capacity times a safety factor of three.

Formulas for computing supporting capacity are as follows:

Cohesive Soils

This category covers clays with an apparent angle of internal friction less than 15E. Capacity is primarily a function of the shear strength of the soil which is established from the unconfined compression tests.

$R_f = \frac{1}{2}\, Qu\, Z\, A_p\, T$ ªd (1)

$R_t = \frac{1}{2}\, Qu\, Y\, A_t$

Where:

R_f = Increment of supporting capacity developed through skin friction, in pounds.

R_t = Increment of supporting capacity developed through tip resistance, in pounds.

Qu = confined compressive strength, in Lbs./Sq. Ft.

Z = Skin friction coefficient (dimension less)

Y = End bearing coefficient (dimension less)

Ap = Average surface area of pile, in Sq. Ft./Ft. of penetration in zone.

A_t = Area of pile tip, in Sq. Ft.

T = Taper coefficient (dimension less)

ªd = Embedded length of pile in zone, in ft.

Where unconfined compressive strength data is inadequate, use Chart J for estimate of Qu based on the standard penetration test blow count.

For values of Z, based on the standard penetration test, use Chart A or Chart C. Chart C has Z' values designated for use in the Lake Agassiz Basin Area (Red River Valley). For remainder of the state, use Z values, Chart A.

For values of Y, based on the standard penetration test (N), use Chart B.

The taper coefficient "T" is considered unity in all areas except in Lake Agassiz Basin clays with "N" less than 20. For values of T, based on the amount of pile taper, use Chart D. When using constant cross-sectional area piles, use taper = O or T = 0.6.

Granular Soils

This category covers sands with an angle of internal friction (∅) considered to be between 25E - 45E. Capacity is considered primarily a function of the confining pressures.

$R_f = n\ K_\emptyset\ P_d$ Sin A_p ªd (3)

$R_t = N_q\ A_t\ P_D$ (4)

Where:

n = Skin friction coefficient (dimension less) used for cases where ∅ (friction angle of soil) differs from (arc tan of coefficient of friction between soil and pile).

$K_\emptyset$ = Factor relating vertical soil pressure to soil pressure acting on pile walls (dimension less).

P_d = Vertical effective pressure in soil at any depth d, in Lbs./Sq. Ft.

P_D = Vertical effective pressure in soil at pile tip, in Lbs./Sq. Ft.

N_q = Factor relating vertical soil pressure to supporting pressure beneath the pile tip.

(R_f, R_t, A_p, A_t, and ªd are same as for cohesive soils.)

The value of confining pressure P_d for a zone is determined by one or both of the following formulas:

Above Water Table: For examples of determining Pd see pages 56 and 228 of FHWA publication "Soils and Foundations Workshop Manual."

$P_d = (W_s \times H_s)$

Below Water Table:

$$P_d = \left(W_s - \frac{Ws}{Sp.Gr.}\right) \times H_s$$

Where:

W_s = Dry weight of soil (Lb./Cu. Ft.) (weight of soil above ground water).

H_s = Height of soil from ground surface to effective depth (Ft.).

Since P_d is a function of H_s, its value will vary from top to bottom of the zone. If the pile will penetrate the full depth of the granular zone, the effective depth will be at a point one-half the full depth of the zone. For partial embedIment in a granular zone, use one-half the embedded depth in that zone. For values of P_D to determine R_t, use effective depth to pile tip.

The friction angle, Ø, is considered a function of the standard penetration test below count (N) and the confining pressure (P_d). Values for Ø can be obtained by reading vertically upward on Chart E to the applicable P_d curve, then horizontally to Chart F.

For values of K, based on the soil friction angle (Ø) and the pile displacement (Cu. Ft./Ft.), use Chart F.

For values of n, based on the soil friction angle (Ø) and sand on pile friction angle ( ), use Chart G.

For values of N_q, based on the soil friction angle (Ø), use Chart H.

<u>Cohesive - Granular Soils</u>

This category covers intermediate sand-clay mixtures. Values of actual Ø are considered to be between 20E-25E. This is the most difficult category to analyze. At present, capacity is considered a function of both the confining pressures and the shear strength of the soil zone in question.

$R_f = [(ZC) + (n\ K\phi Pd\ Sin\ \ )]\ A_p{}^a d$ (5)

$R_t = [(YC) + (N_q\ P_D)]\ A_t$ (6)

Where:

C = Cohesion, in Lbs./Sq. Ft.

All other terms are as defined under cohesive and granular soils.

For values of cohesion (C), based on the unconfined compression (Q_u), use <u>Chart I</u>.

The sand portion is considered independently when determining values of n, K_ϕ, , P_d, P_D, and N_q. Use same procedure as outlined under granular soils.

For the clay portion, determine values of Y and Z as outlined under clay soils.

2. <u>GENERAL NOTES</u>:

a. Each zone which pile is assumed to penetrate delivers a portion of the total bearing capacity based on the appropriate R_f values determined by application of the formula for that particular zone.

   Tip resistance (R_t) is computed on values obtained from the soil zone which tip is finally embedded. As 3R_f approaches the required bearing, solve for the applicable tip supporting capacity (R_t) in zone which tip is embedded by use of formulas (2), (4), or (6). For clays, rearrangement of formula (1) to solve for ^{a}d will determine penetration into the lowest embedded zone. For sands and sand-clay mixtures, solution by trial and error is usually the easiest method for determining penetration into the lowest embedded zone.

b. In some cases where piles are embedded in soft silt or clay and obtain most of their bearing capacity by friction, it is necessary that the computation of the safe design load be supplemented by a computation of the ultimate bearing capacity of the entire group.

As a rule of thumb, this group bearing capacity reduction should be made on piles which have a spacing closer than 4 pile diameters.

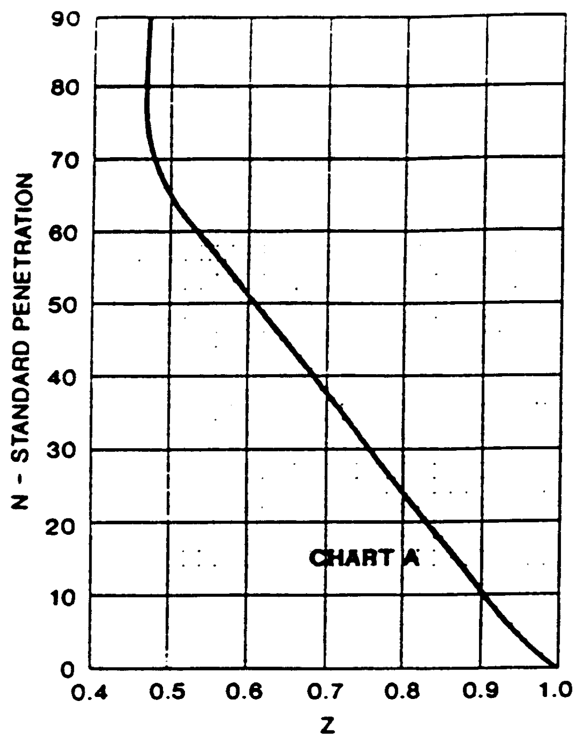
Formula: Converse-Labarre method as recommended by AASHTO.

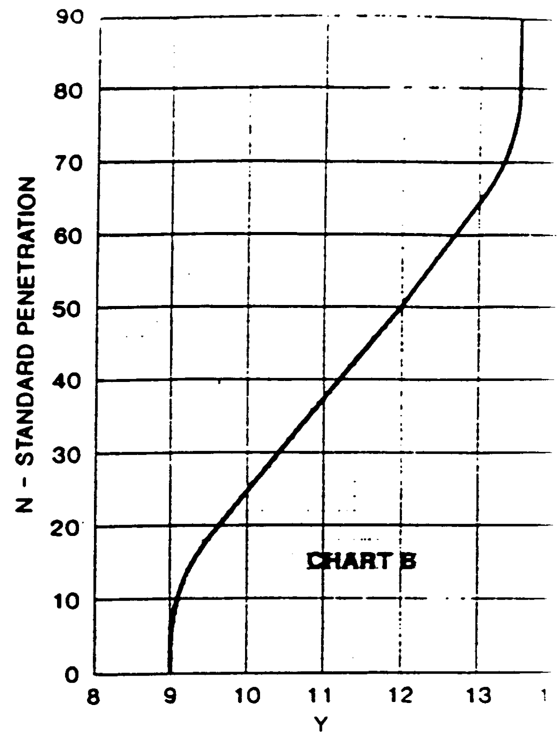
No reduction due to grouping is computed when piles are end bearing piles. For groups which partake of both actions, only the portion in friction is reduced.

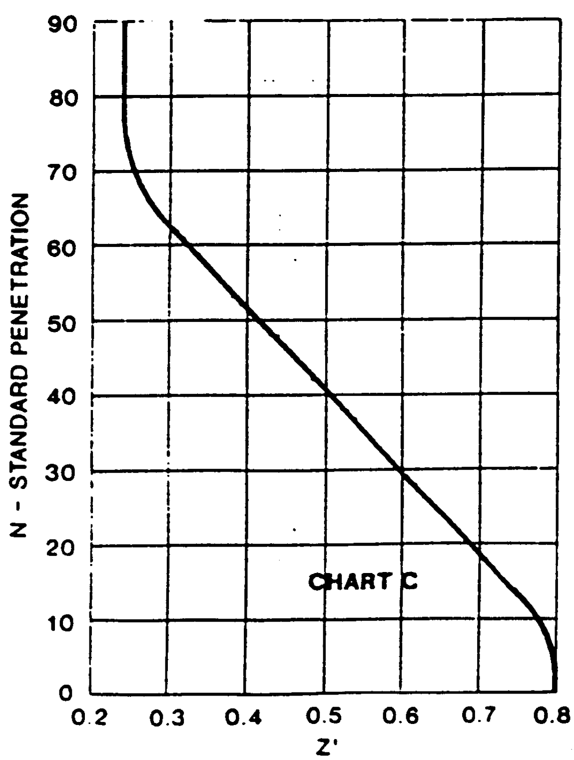
c. When determining the average pile area per foot (A_p) neglect inside flanges and web of H-beam piles and use as a rectangle.

d. Vertical pressures at the pile point while resting on any hard layers of coal or rock is assumed to spread uniformly within a cone (or rectangle) the sides of which are inclined 60E to the horizontal. Safe supporting capacity of any underlying soft material should be analyzed by methods applicable to spread footing design.

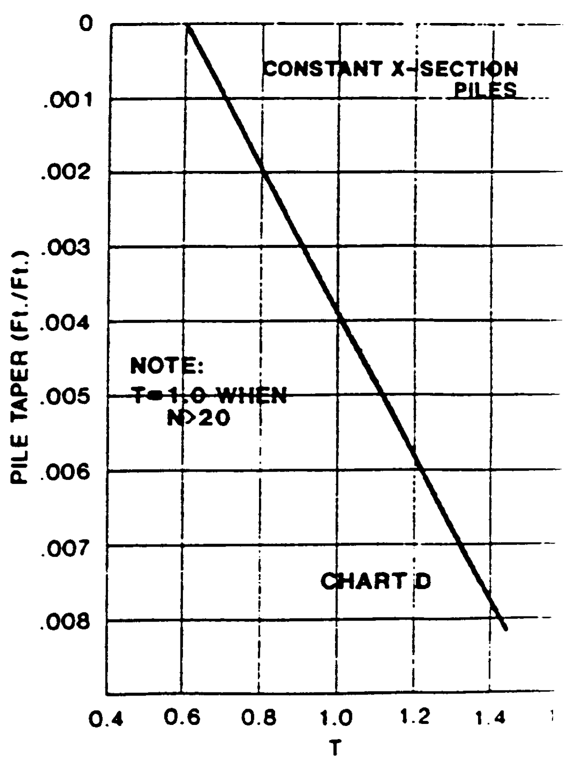
e. Negative friction induced by long term settlement of abutment fills overlaying soft cohesive soils should be accounted for when predetermining abutment pile lengths.



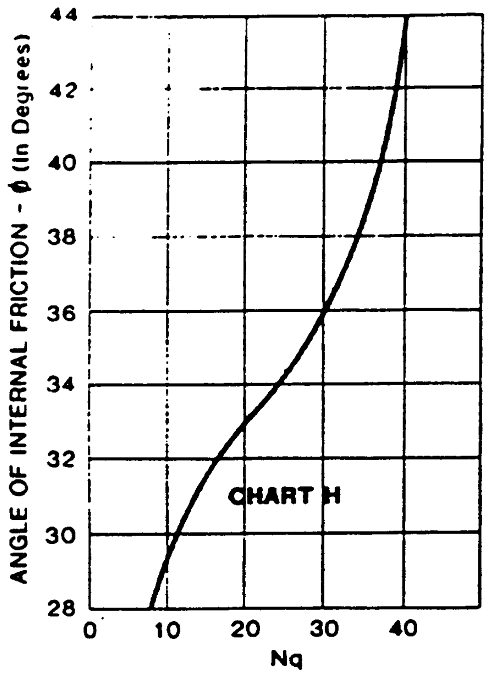


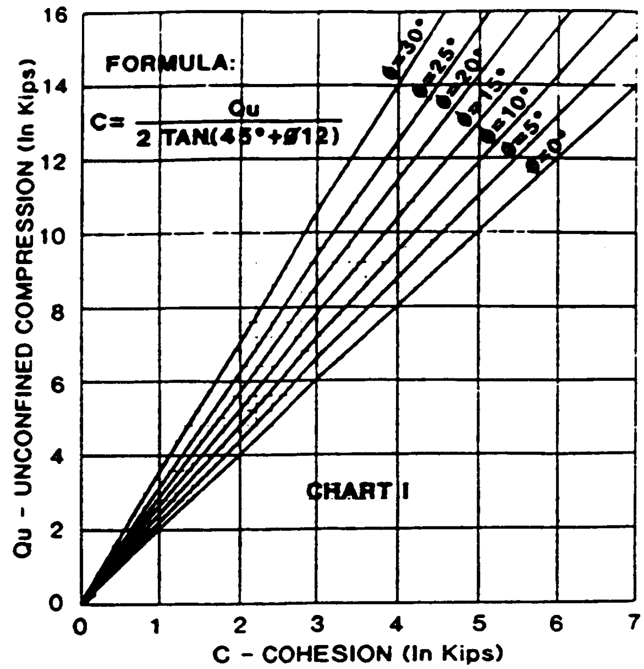


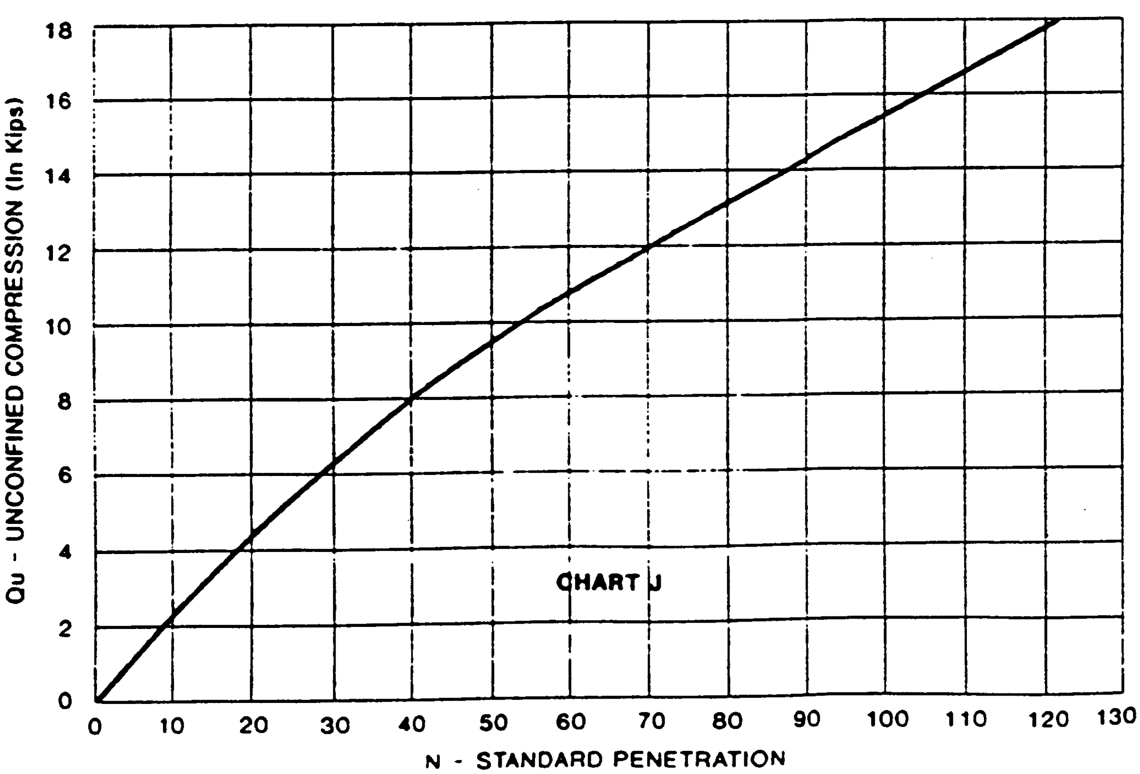
(LAKE AGASSIZ BASIN ONLY)

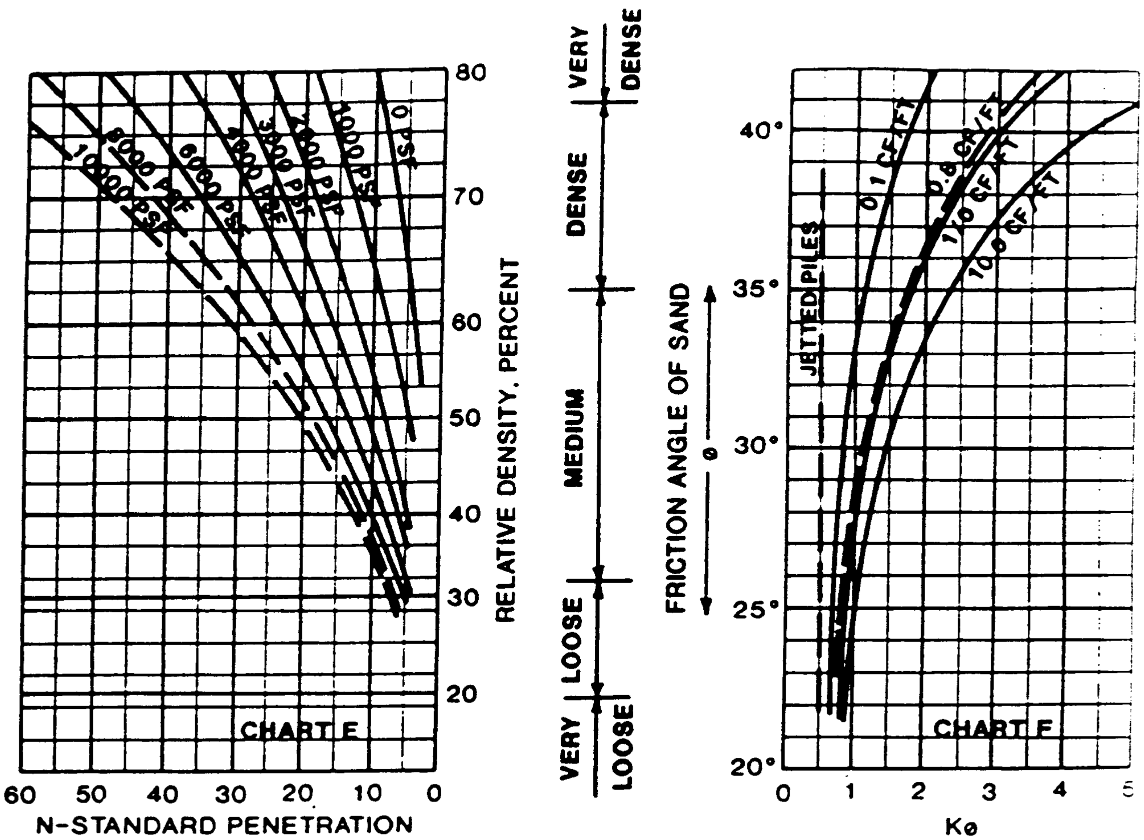


(LAKE AGASSIZ BASIN ONLY)


ANGLE OF INTERNAL FRICTION - ϕ (In Degrees)
44
42
40
38
36
34
32
30
28
0
10
20
30
40
Nq
CHART H


Qu - UNCONFINED COMPRESSION (In Kips)
16
14
12
10
8
6
4
2
0
FORMULA:
C= Qu / 2 TAN(45°+ϕ/2)
ϕ=30°
ϕ=25°
ϕ=20°
ϕ=15°
ϕ=10°
ϕ=5°
ϕ=0°
CHART I
0
1
2
3
4
5
6
7
C - COHESION (In Kips)


Qu - UNCONFINED COMPRESSION (In Kips)
18
16
14
12
10
8
6
4
2
0
CHART J
0
10
20
30
40
50
60
70
80
90
100
110
120
130
N - STANDARD PENETRATION



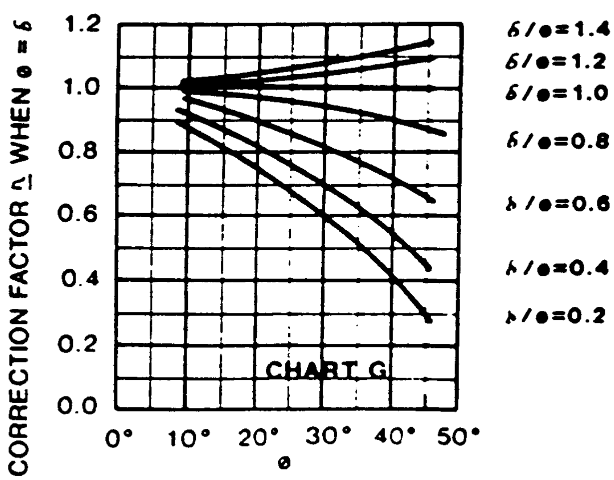
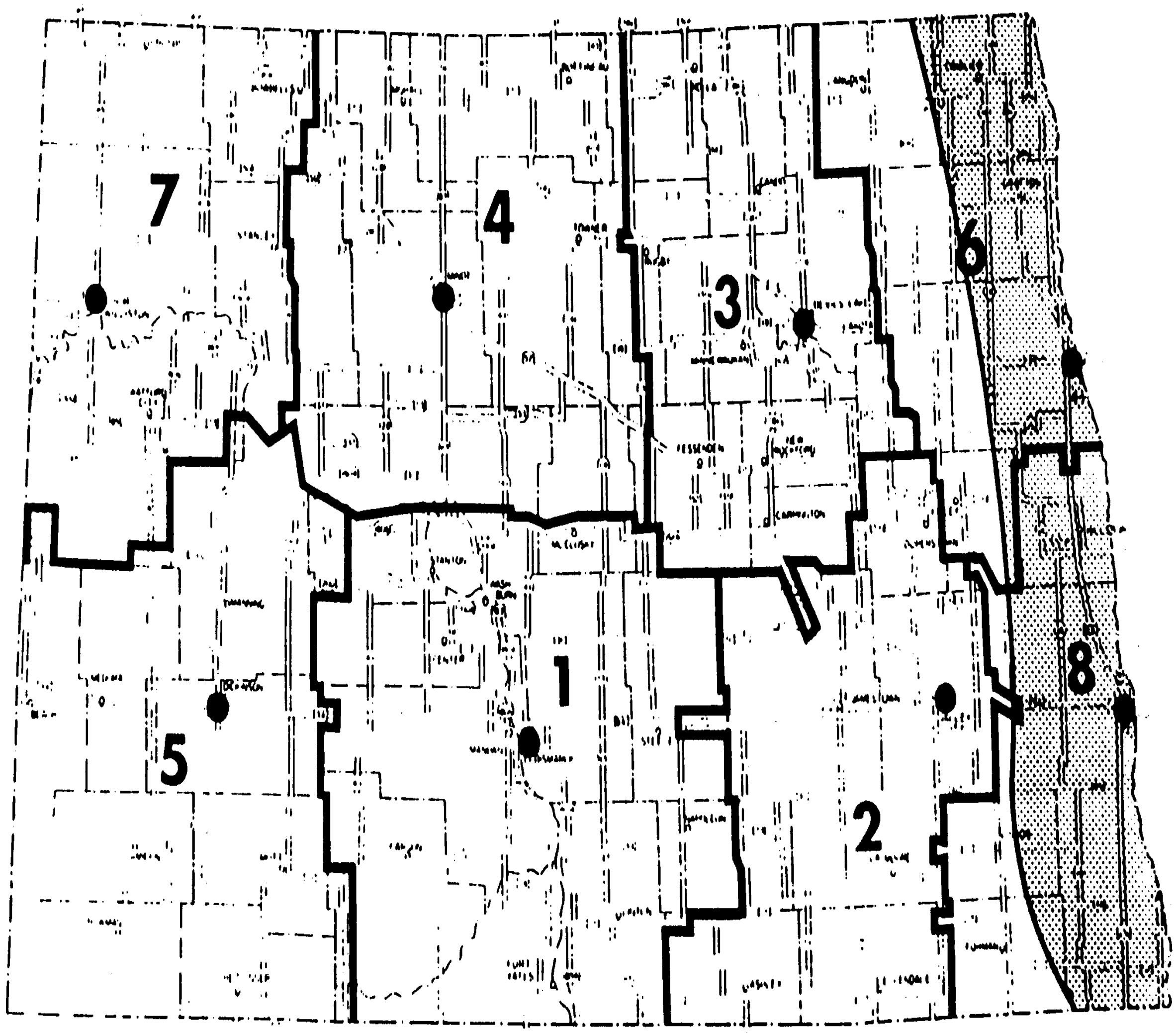


Figure 9. Friction factors for piles in granular soil: friction angle δ for sand on steel=18.5° (for piles with no appreciable taper).

assumed δ on wood=16°

NOTE: Charts E thru F taken from Michigan State Highway Department "Recommendations For Pile Design And Driving Practices."

North Dakota Department of Transportation



-Lake Agassiz Basin

District Boundaries

Appendix IV-04 E

Installation of Utilities on Highway Structures

1. General Features

   a. Attachments to bridge structures should be avoided where it is reasonable to locate facilities elsewhere. However, where other locations prove to be difficult and unreasonably costly, attachment of utility facilities to a bridge structure will be considered, provided the attachment can be made without materially affecting the structure, the safety of traffic, or the efficiency of maintenance of the structure, or the efficiency of bridge inspection, or its appearance, and provided the structure can support the additional load.

   b. Generally, utility installations shall be attached to the bridge structure beneath the structure's floor, between the outer girders or beams or within a cell, and at an elevation above low superstructure steel or masonry.

   c. The location of utility facilities on a structure which will interfere with access to parts of the structure for painting or repair will not be permitted. Manholes for utility access will not be permitted in the bridge deck.

   d. The utility installation on the bridge shall be mounted so as not to reduce the vertical clearance above river, stream, pavement or top of rails. Utility attachments to the outside of bridges will not be permitted unless there is no reasonable alternative.

   e. Utility facilities shall be firmly attached to the bridge structure and padded, where necessary, to eliminate noise and abrasion due to vibrations caused by wind and traffic.

   f. Installation of utility facilities through the abutment or wingwall of an existing bridge will not be permitted.

   g. In locations where a utility facility attached to a structure is carried beyond the back of the bridge abutment, the facility shall curve or angle out to its proper alignment outside the roadbed area as quickly as is practicable.

   h. Utility facilities may be attached to structures by hangers or roller assemblies suspended either from inserts in the underside of the bridge floor or from hanger rods clamped to a flange of a superstructure member. Bolting through the bridge floor or concrete beams will not be permitted. Welding of attachments to steel members, or bolting through such members, will not be permitted. Where there is transverse bridge steel extending sufficiently from the underside of the bridge floor to provide adequate clearance, utility facilities may be installed on rollers or neoprene padded saddles mounted atop such transverse members.

i. The design of a utility facility attached to a highway structure shall include satisfactory provisions for lineal expansion and contraction due to temperature changes. Line bends or expansion couplings may be used for this purpose. Materials used for attaching a utility facility to the structure shall be compatible with the structural material to eliminate the possibility of corrosion.

j. A utility facility and associated appurtenances attached to a highway structure shall be painted when requested by the Department. The type and color of the paint shall be approved by the District Engineer.

k. Each proposed bridge attachment will be considered on its individual merits by the Department.

2. New Bridge Structures

a. Where the Department plans to construct a new bridge structure, the design of the structure will, upon request of a utility company, be reviewed for accommodation of existing or proposed utility installations consistent with the requirements set forth herein. The utility company may be required to reimburse the state for any additional costs associated with accommodation of the utility facility in the new structure.

b. Installation of a facility by a utility company on a new structure shall be coordinated with the bridge construction so as not to interfere with the operations of the highway contractor.

3. Pipelines

a. Pipelines attached to a highway structure shall be encased throughout the bridge, and the casing shall be carried beyond the back of the bridge abutment and shall be effectively opened or vented at each end. The casing pipe shall be designed to withstand the same internal pressure as the carrier pipe.

b. The carrier pipe shall be pressure tested before start-up in accordance with the latest edition of applicable industry codes, or appropriate regulations of an agency of the federal government.

c. Emergency shut-off valves shall be installed on all pipeline attachments to a highway structure where such pipeline carries gas or liquid petroleum or other hazardous materials under pressure. The shut-off valves shall preferably be of automatic design, and shall be placed within an effective distance on each side of the structure, unless the pipeline is equipped with nearby shut-off valves or operates under effective control of automatic devices.

d. Pipelines carrying liquids subject to freezing shall be insulated to prevent the liquids from freezing.

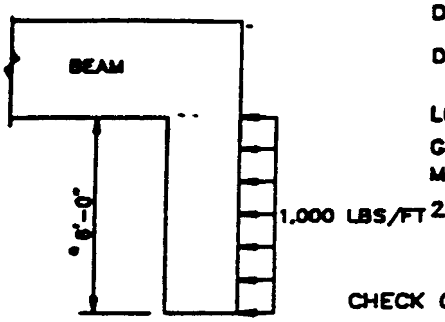
4. <u>Power and Communication Lines</u>

a. Electric power and communication lines attached to a highway structure shall be insulated from the structure, and carried in protective conduit or pipe throughout the bridge and to underground locations at each end of the structure. Exposed metallic conduit carrying electrical cables shall be grounded separately from the structure.

b. Attachments for electric power and communication lines shall provide sufficient clearance for convenience and safety during maintenance and repair of bridge structure or other utility installations on the bridge.

Appendix IV–04 F Integral Abutment Design

INTEGRAL ABUTMENT DESIGN



DESIGN AS A CANTILEVER ABOUT BOTTOM OF BEAM.

DESIGN MOMENT = $1000(6)^2/2$ = 18,000 FT.-LBS/FT

LOAD FACTOR DESIGN

GROUP I β_E = 1.0 BRIDGE POLICY

Mu = 1.3(1.0 X 18,000) = 23,400 FT-LBS/FT

CHECK CAPACITY OF #5's ● 12" SPACING (MIN. REINF.)

AASHTO 8.16.3.2 F'c = 3000 PSI fy = 60,000 PSI b = 12"

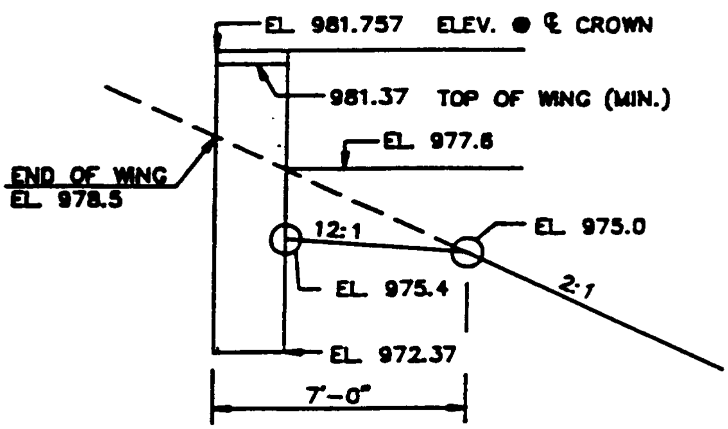
d = 24 − 2 − .625/2 = 21.69 IN As = $.31\ IN^2$

$$a = \frac{.31\ (60000)}{.85\ (3000)\ 12} = .61$$

ϕ Mn = ϕ As fy (d − a/2) = .9 (.31) 60,000 (21.69 − .61/2) = 357,985 IN − LBS OR 29,832 FT-LBS

Mu < ϕMn ∴ USE #5' S ● 12" SPACING FOR VERTICAL STEEL

- MAX L FOR # 5s ● 12" $1.3(1.0)(L)^2/2$ = 29.832 L = 6.77'

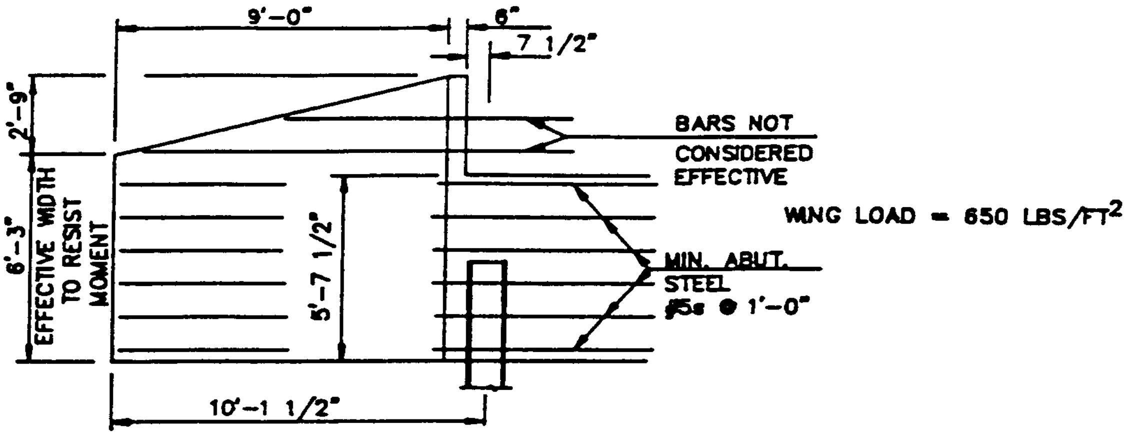


ELEV. ℄ CROWN	981.757
CROWN	−.25(18.5)/12
TOP OF WING ELEV.	981.37

	981.37
	−978.5
TOP OF WING ELEVATION CHANGE	2.87

● 3:1 SLOPE WING LENGTH = 2.87' X 3 = 8.61' OR 9'

WHEN POSITIONING PILE IN THE ABUTMENT TRY TO LOCATE THE OUTERMOST PILES UNDER THE EDGE OF THE SLAB.
THE WING MOMENTS ARE CALCULATED ASSUMING THE WING IS CANTILEVERING FROM THE PILE.



BENDING MOMENT

$M = 650\ (5.625)(10.125)^2/2 + 650\ (.625)\ 9.5\ (5.375) + 650\ (2.75)\ 1/2\ (9.0)\ (4.125)$
$+ 650\ (2.75)\ .5\ (.875) = 242{,}118$ FT–LBS

GROUP I $\quad M_u = 1.3\ (1.0 \times 242{,}118) = 314{,}753$ FT–LBS

$b = 6'{-}3"$ OR $75.0"$ $\quad d = 24 - 2 - .625 - \dfrac{.625}{2} = 21.06"$

$f'c = 3000$ PSI $\quad fy = 60{,}000$ PSI $\quad \phi = .9$

USE AASHTO EQUATION 8–16 & 8–17

$$A_s \geq \left[\frac{bdf'c}{.6fy} - \sqrt{\left(\frac{bdf'c}{.6fy}\right)^2 - \frac{4\ Mu\ b\ f'c}{.6\ \phi\ fy^2}}\right] /2$$

$$A_s \geq \left[\frac{75.0(21.06)3}{.6(60)} - \sqrt{\left(\frac{75.0(21.06)3}{.6(60)}\right)^2 - \frac{4(314.75 \times 12)\ 75.0\ (3)}{.6\ (.9)\ (60)^2}}\right] /2$$

$A_s \geq 3.41\ IN^2$

WITH #5s @ ABOUT 1'–0" THERE ARE 6 #5s $\quad A_s = 1.86$

AREA OF ADDITIONAL STEEL $\quad 3.41 - 1.86 = 1.55\ IN.^2$

ADD 4 #6 BARS $\quad A_s = 1.76\ IN.^2$

ADD 4 #6 BARS FRONT AND BACK FACE THAT SHOULD EXTEND AT LEAST THE DEVELOPMENT LENGTH BEYOND THE PILE INTO THE ABUTMENT.

BARS THAT EXTEND FROM THE WING TO THE ENDWALL ARE NOT CONSIDERED EFFECTIVE.

Appendix IV–04 G

Installation Details of Precast RCB's

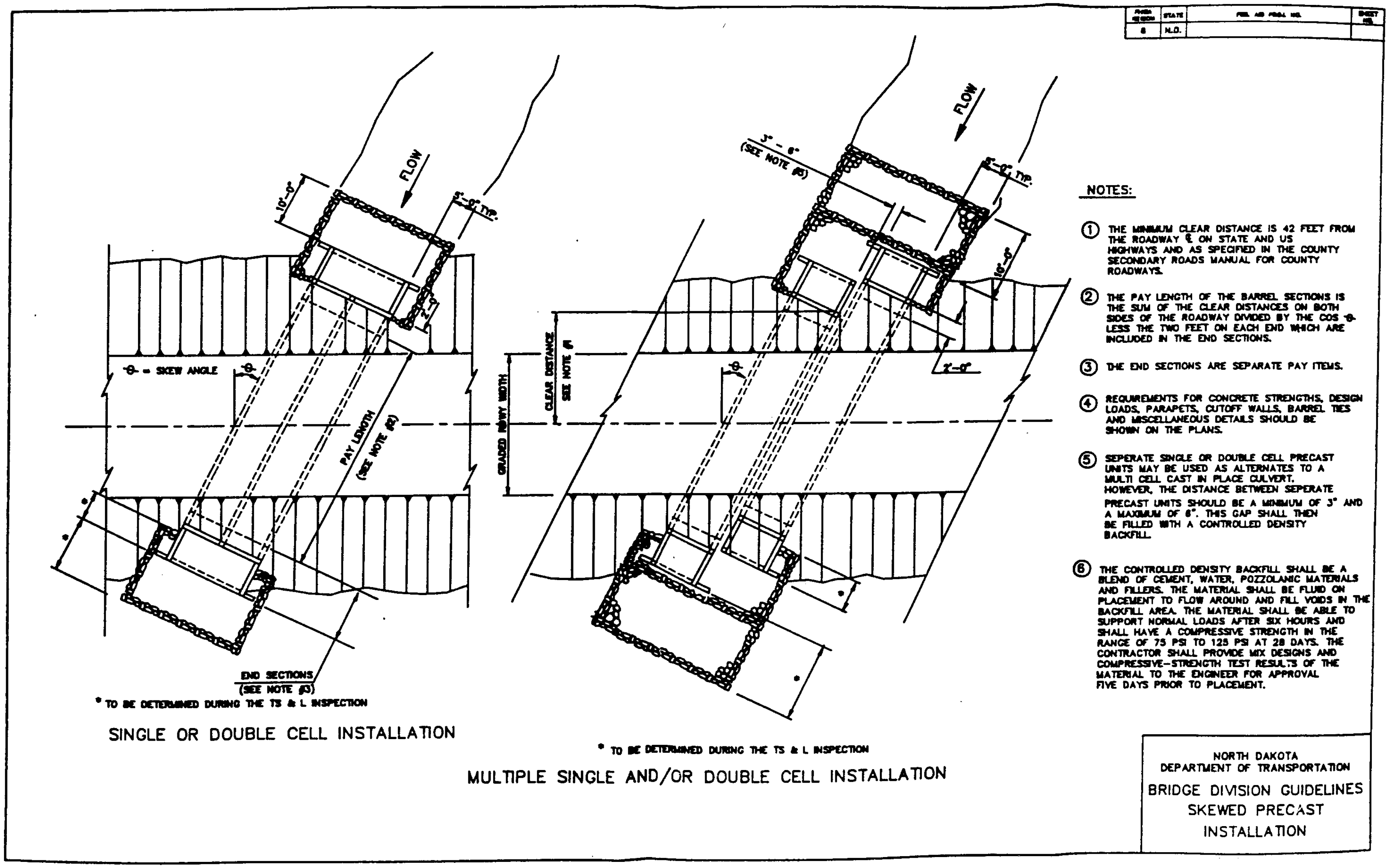
The following steps will generally govern in the installation of RCB's:

1. All excavation will be class II and will be lump sum.

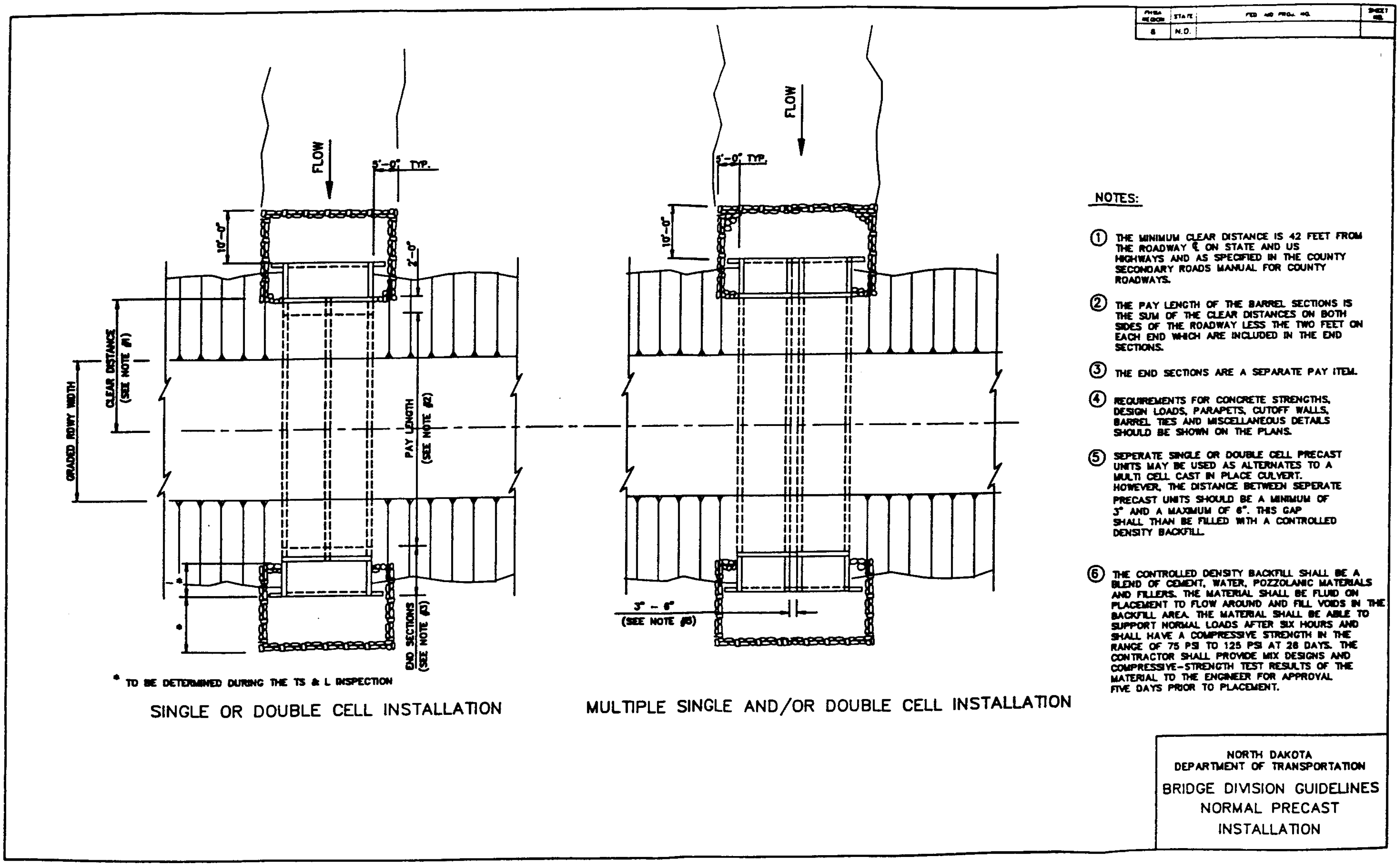
2. This will be a lump sum item and the Bridge Division will provide an estimated quantity on the plans.

3. The Design Division will add the RCB to the cross sections.

Appendix IV–04 G 1 Skewed Precast RCB Installation Guidelines



Appendix IV–04 G 2 Normal Precast RCB Installation Guidelines



Appendix IV–04 H Installation Details of Precast RCB's

CHECKLIST FOR BRIDGE PLANS

North Dakota Department of Transportation, Bridge
SFN 17180 (Rev. 1-2000)

Bridge No.	Project No.	Checked by	Date

Layout Sheet: (Items marked with * may appear on another sheet)

1. Bridge Code
2. Project No. Upper Right
3. North Arrow
4. Centerline Roadway Indicated
5. Begin and End Sta. and Elevations
6. Intermediate Sta. and Elevations
7. Roadway Width
8. Overall Length
9. Span Lengths
10. Fixed and Exp. Supports Indicated
11. Vertical Clearance
12. Horizontal Clearance
13. Structural Clearance Line
14. Test Piles Shown (if used)*
15. Boring Log Locations
16. Pile Loads*
17. Min. Pile Penetration*
18. Spread Footing Loads*
19. Bearing Plate Layout*
20. Berm Width
21. Berm Elev. (12 to 1)
22. Riprap - Slope Protection
23. Bottom of Footing Elev.
24. Substructure Units Numbered
25. Vertical Curve Data*
26. Benchmarks*
27. Screed Elevations (Each Girder)*
28. Original Ground Line
29. Piling Length Indicated
30. Correct Spec. Nos.*
31. List Special Provisions*
32. Enter Quantities*
33. Pounds of Structural Steel*
34. Enter Drwg. Nos.*
35. Design Loading (& Design Method)
36. Layout Titles
37. Project Number and Station
38. County
39. Drawing Number
40. Skew Indicated
41. Pay Quantity Limits*
42. Seepage Trench Shown
43. Approach Slab Shown
44. Datum Line
45. Bridge Cross Section*
46. Design Future Wearing Surface (F.W.S.)*
47. PE Stamp
48. List of Standards*
49. Hydraulic Data*

Note Sheet

1. Scope of Work
2. Miscellaneous Item Costs
3. Predrill thru Embankment
4. Embankment in Place Before Driving Pile
5. Reing. Steel Dimensions
6. Concrete Surface Finish
7. Cl. of Concrete and Type Coment
8. Approved Finishing Machine
9. Slope Protection
10. Riprap
11. General Pile Note
12. Removal of Existing Structure
13. Salvage and Disposal
14. Channel Excavation
15. Design Stresses (psi)
16. Classes of Excavation
17. Pile Hammer Size
18. Penetrating Water Repellent Trt. (optional)
19. Concrete Removal (Units and Quant.)
20. Anti-Graffiti
21. Bridge Approach Slabs
22. Deck Concrete Thickness Variations
23. Type of Structural Steel
24. Barrier Joint Spacing
25. Shop Drawing Requirements
26. Design Strengths
27. Design Method (Load Factor)

Other Detail Sheets

1. Detail Exp. Jt. Bevels
2. Field Riser Diagram
3. Riser Diagram Note
4. Blocking Diagram
5. Shop Camber Diagram
6. Concrete Placing Sequence
7. Field Bolt Placement
8. Drain Hole Location
9. Charpy V-Notch Test Req.